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(54) **SYSTEMS AND METHODS FOR GENERATING GEOFENCES**

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G08G 1/00 (2006.01)
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G06F 16/955 (2019.01)

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CPC **G08G 1/207** (2013.01); **G06F 16/955** (2019.01); **G06F 16/9537** (2019.01)

(58) **Field of Classification Search**
USPC 340/992
See application file for complete search history.

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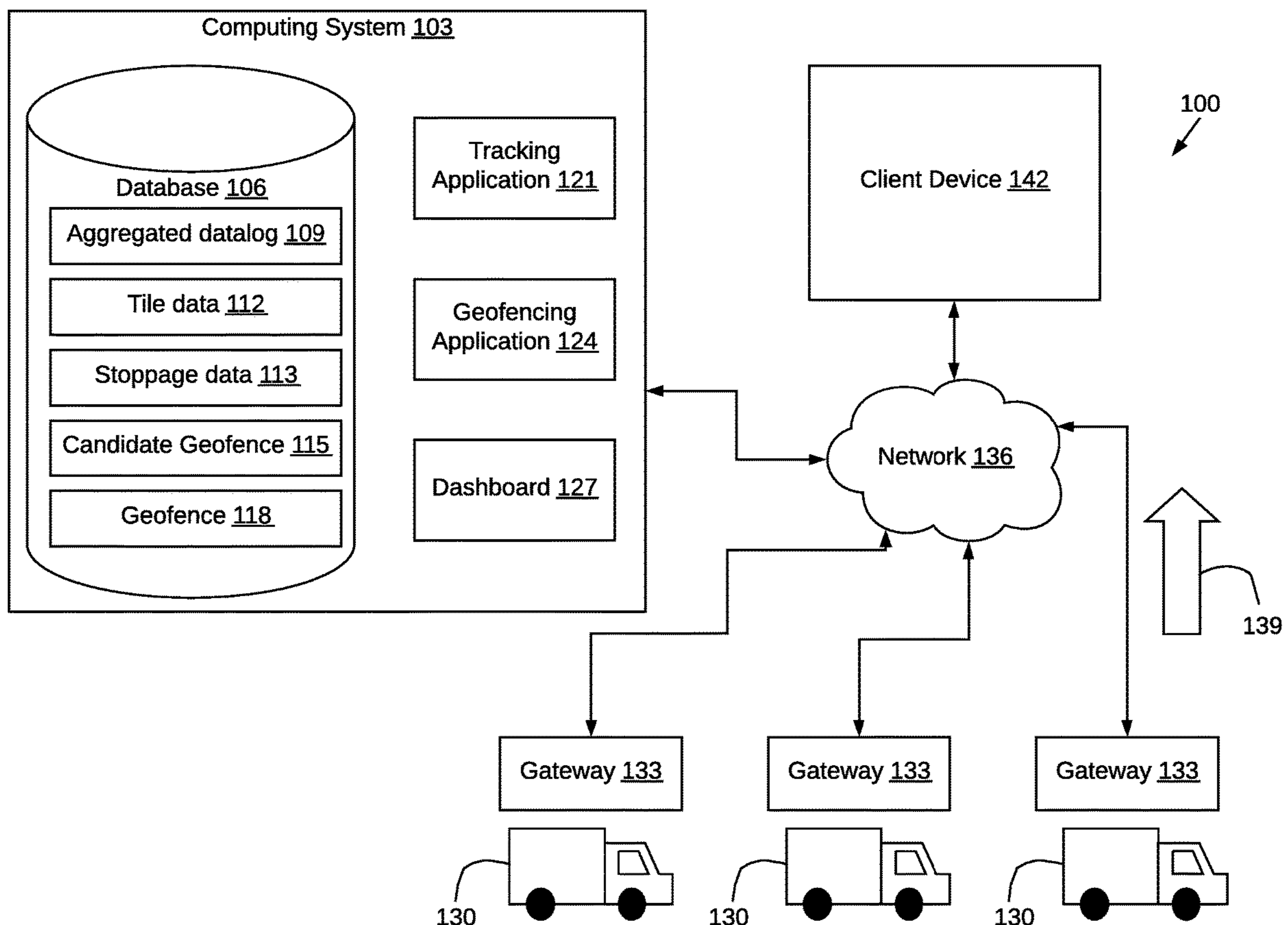
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(57) **ABSTRACT**

The present disclosure relates generating a geofence based on messages received periodically from a plurality of vehicles. A candidate geofence is approximated based on vehicle stoppage data obtained from a datalog of messages. For a given candidate geofence, additional stoppage data is obtained to identify additional vehicle stoppages. The locations of these additional vehicle stoppages are binned to a corresponding geospatial tile. A relatively large cluster of contiguous geospatial tiles form a geofence that may be transmitted to a client device.

17 Claims, 8 Drawing Sheets



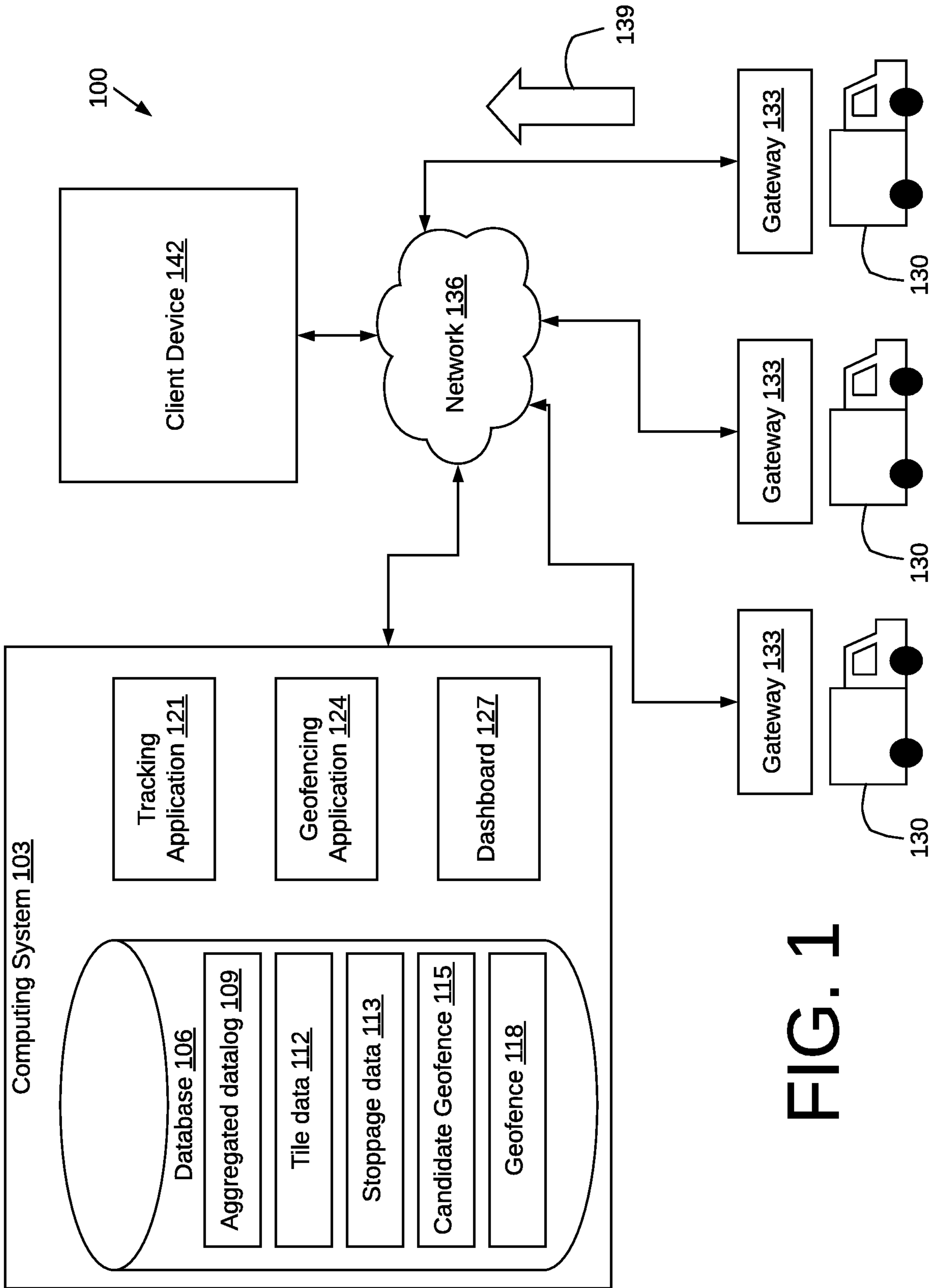


FIG. 1

109 ↘

Gateway 001	Gateway 002	Gateway 003	Gateway <i>n</i>
Location: (33.7, -84.3) Speed: 15mph Timestamp: 00:00:12	Location: (44.4, -24.3) Speed: 15mph Timestamp: 00:00:03	Location: (44.5, -24.3) Speed: 0mph Timestamp: 00:00:09	
Location: (33.8, -84.2) Speed: 15mph Timestamp: 00:00:42	Location: (44.5, -24.3) Speed: 2mph Timestamp: 00:00:33	Location: (44.5, -24.3) Speed: 0mph Timestamp: 00:00:39	
Location: (33.9, -84.2) Speed: 20mph Timestamp: 00:01:12	Location: (44.5, -24.3) Speed: 0mph Timestamp: 00:01:03	Location: (44.5, -24.3) Speed: 0mph Timestamp: 00:01:09	
Location: (34.0, -84.2) Speed: 15mph Timestamp: 00:01:42	Location: (44.5, -24.3) Speed: 0mph Timestamp: 00:01:33	Location: (44.4, -24.3) Speed: 5mph Timestamp: 00:01:39	

FIG. 2A

113



Stoppage Location	Duration
Location: (33.7, -84.3)	28
Location: (33.8, -84.2)	18
Location: (33.9, -84.5)	44
Location: (48.0, -60.3)	4
Location: (54.3, -70.2)	11
Location: (54.3, -70.2)	3

nearby locations

nearby locations

FIG. 2B

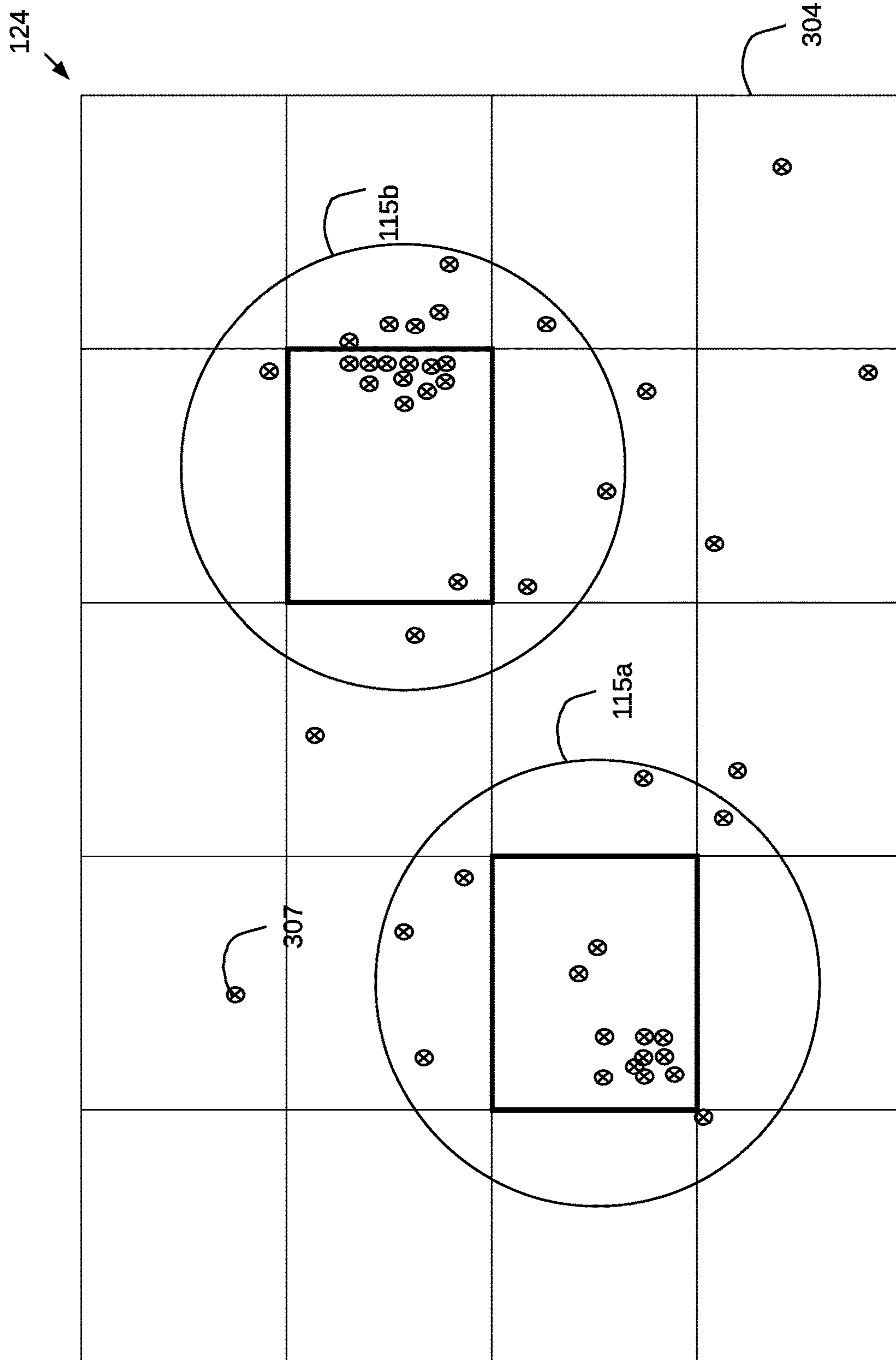


FIG. 3

124
↙

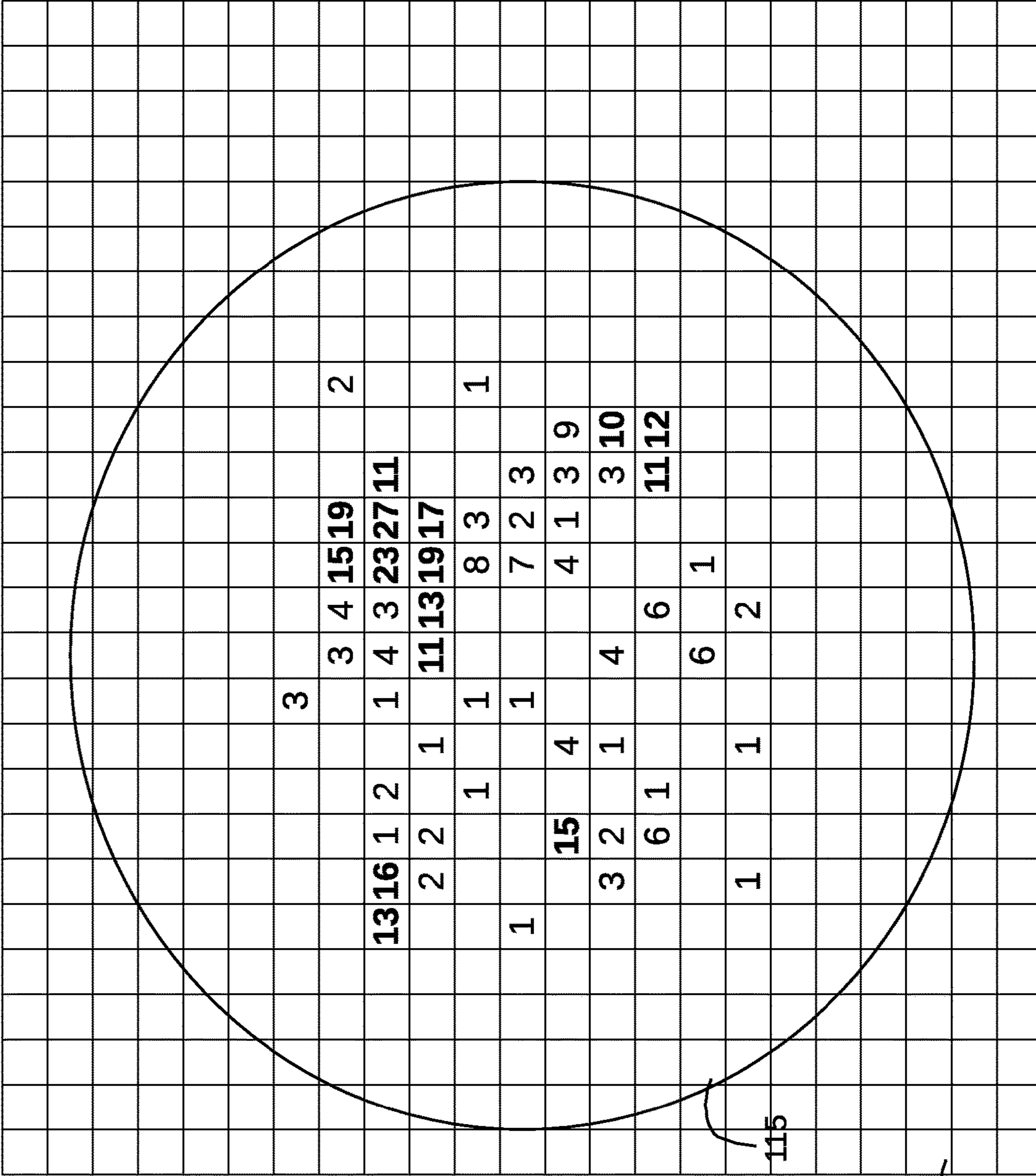


FIG. 4A

115

407

124

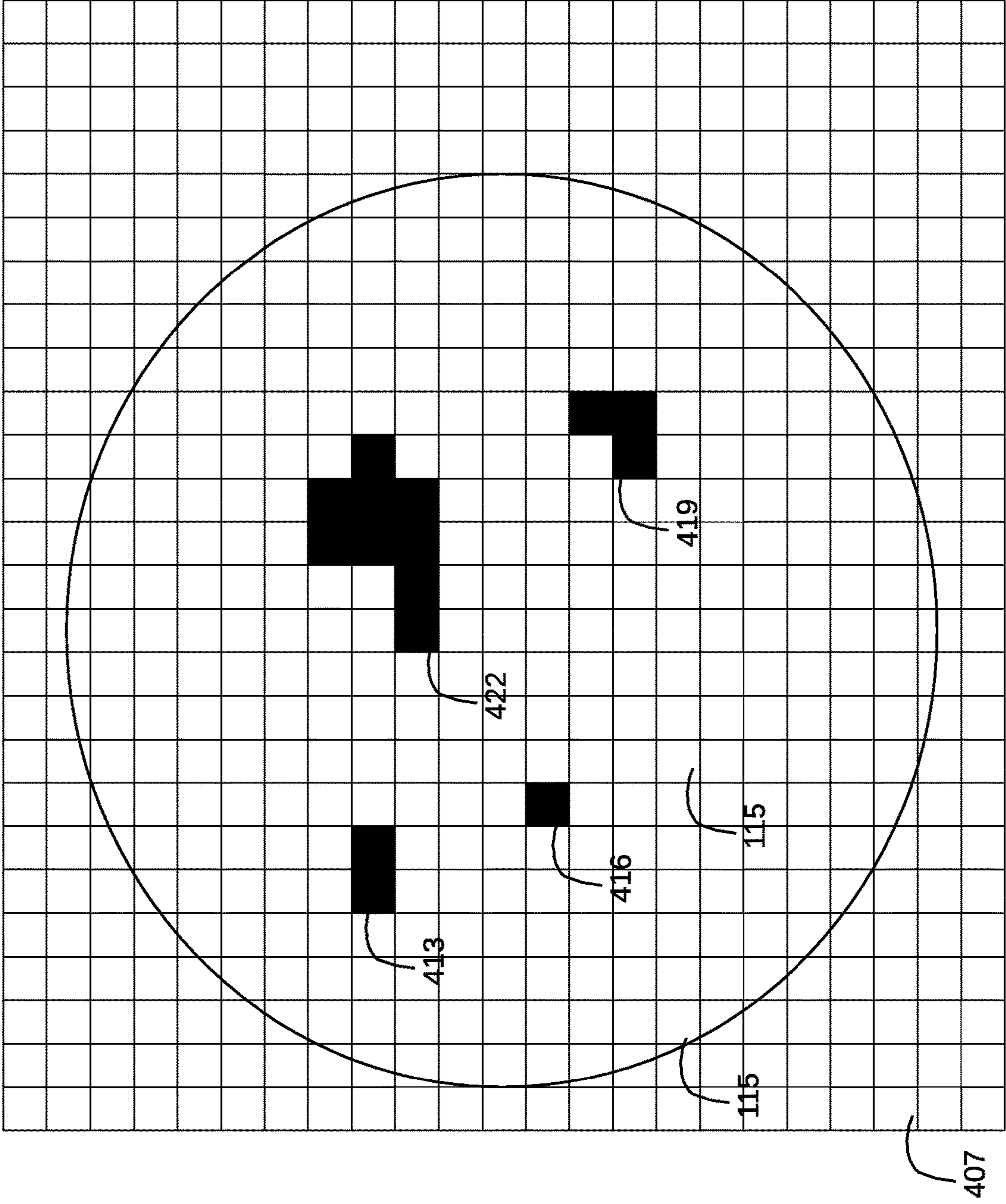


FIG. 4B

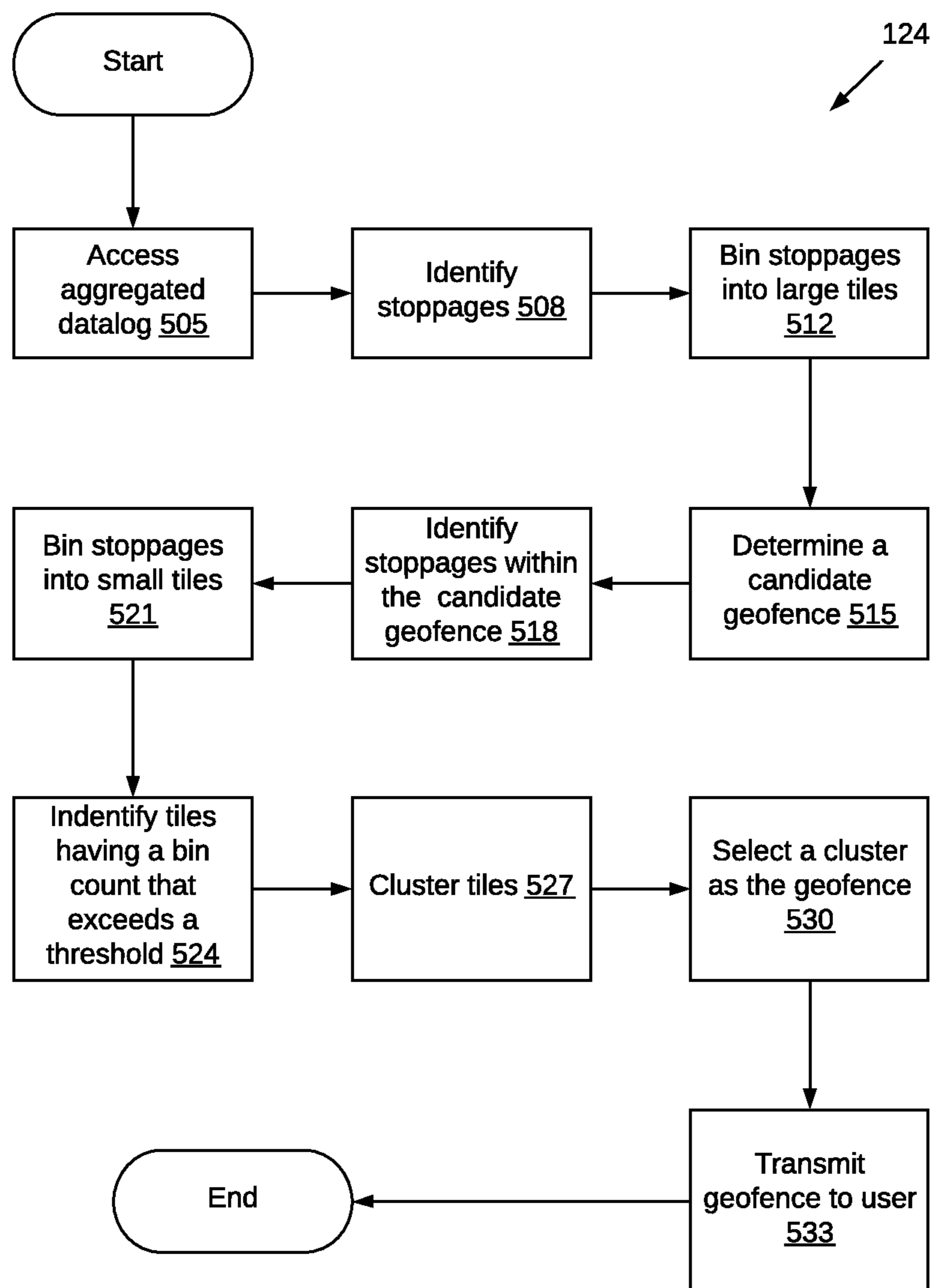


FIG. 5

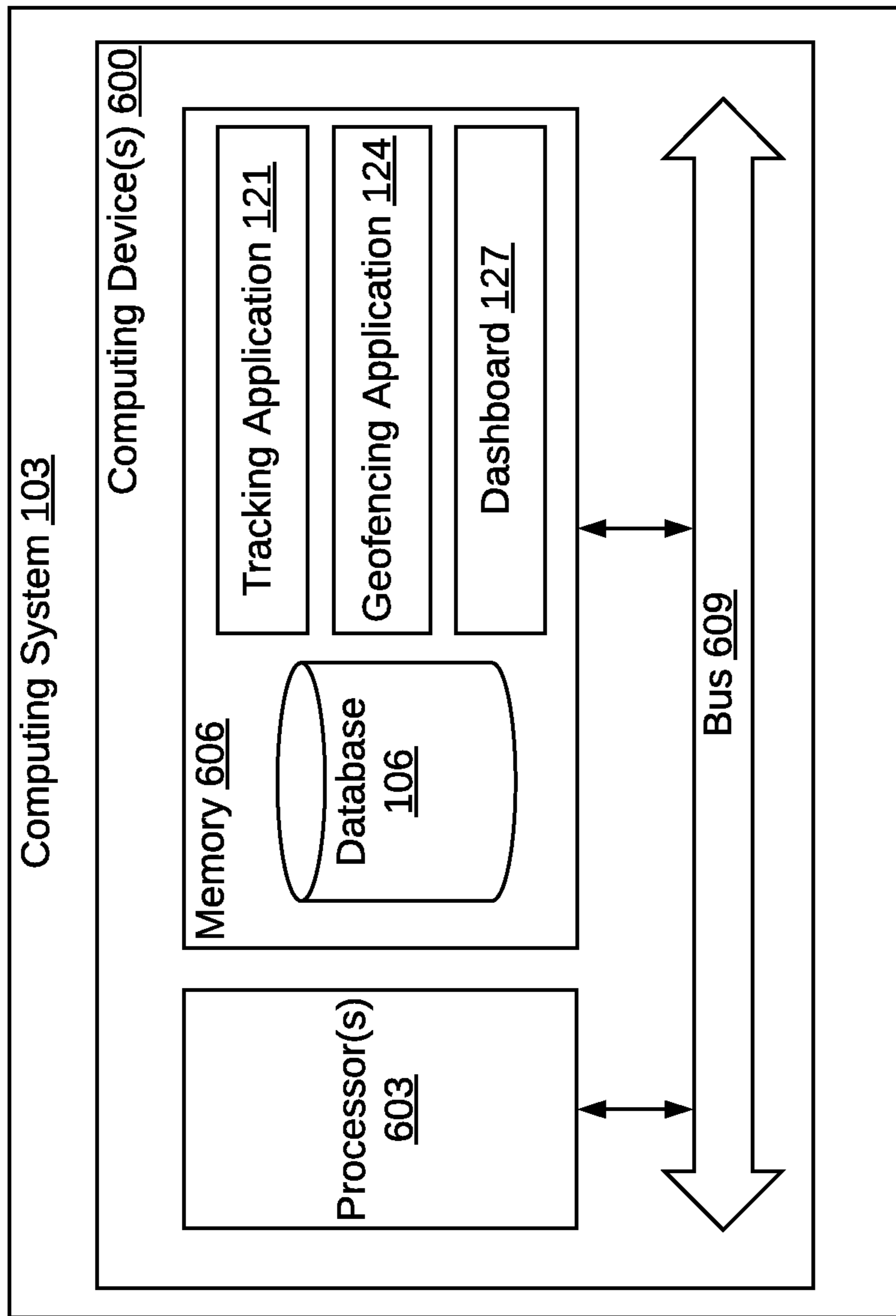


FIG. 6

SYSTEMS AND METHODS FOR GENERATING GEOFENCES

BACKGROUND

A vehicle gateway tracks the parameters of the vehicle and transmits it to a central server so the vehicle can be tracked. A fleet manager may deploy vehicle gateways in its fleet vehicles so that it can track the location of each vehicle in its fleet. The fleet manager may have access to a user interface to view the location of its fleet vehicles. In addition, the fleet manager may manually draw a geofence on a map so that a geofence crossing event is logged. In this respect, a geofence is geospatial boundary that may be defined on a coordinate system. A geofence may be visualized on a map.

As described in further detail below, the present disclosure recognizes that there are several drawbacks to the manual creation of geofences. The creation of manual geofences requires significant human input and judgment. Moreover, a manually created geofence might not align with real world results. The present disclosure addresses these issues as well as other issues.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present disclosure can be better understood with reference to the attached drawings. The components in the drawings are not necessarily drawn to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. 1 is a drawing of a computing environment **100** according to various embodiments of the present disclosure.

FIG. 2A is a drawing illustrating an example of an aggregated datalog **109**, stored, processed, and accessed in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure.

FIG. 2B is a drawing illustrating an example of stoppage data **113**, stored, processed, and accessed in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure.

FIG. 3 is a drawing illustrating an example of operations performed by a geofencing application that executes in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure.

FIGS. 4A and 4B are drawings illustrating an example of operations performed by a geofencing application that executes in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure.

FIG. 5 is a flowchart illustrating an example of the functionality of the geofencing executed in a computing environment **100** of FIG. 1.

FIG. 6 is a schematic block diagram that provides one example illustration of a computing system **103** of FIG. 1 according to various embodiments of the present disclosure.

DETAILED DESCRIPTION

Various embodiments of the present disclosure relates to generating a geofence based on extracting vehicle stoppage data from periodic vehicle tracking data. The vehicle stoppage data is collected from fleets of vehicles to identify areas that likely correlate to an area where vehicles stop for a significant period of time. Moreover, through the use of a multi-step algorithm of identifying a candidate geofence and

then narrowing the boundaries of that candidate geofence, a highly specific geofence is generated.

The geofences according to the present disclosure are, therefore, recommended based on vehicle data. In other words, through detailed data analysis, the present disclosure identifies and recommends geofences to users (e.g., fleet managers), as opposed to the users defining their own geofences from scratch. As a result, the present disclosure provides insight that might not be readily apparent to a user who is tracking a fleet of vehicles.

For example, assume that there are 1,000 vehicles in a fleet driving over a particular region of a country. A fleet manager may be aware of where these vehicles typically begin and end their trips. The fleet manager may also be aware of one or more depots along the way between the beginning and ending of these trips. The fleet manager may manually create geofences to monitor when a fleet vehicle enters or exits a geofence. However, employing embodiments of the present disclosure, the fleet manager may learn his or her vehicles spend a significant amount of time stopping at a particular area. In addition, the present disclosure defines such an area as a recommended geofence with specific boundaries.

According to various embodiments, a specific geofence is generated based on a collection of relatively small, contiguous, geospatial tiles that define a geofence regardless of landmarks on a map. Rather than defining a geofence using roads or a predefined perimeter around a landmark (e.g., a rest area, a depot, etc.), the present disclosure is driven by deriving actual stoppage data from vehicles deployed in the field. As a result, a generated geofence may correspond to a particular parking lot or section of a parking lot, even if that parking lot is not near a rest area or depot. While the foregoing provides a high level summary, the details of the various embodiments may be understood with respect to the Figures.

FIG. 1 shows a computing environment **100** according to various embodiments. The computing environment includes a computing system **103** that is made up of a combination of hardware and software. The computing system **103** may comprise, for example, a server computer or any other system providing computing capability. Alternatively, the computing system **103** may employ a plurality of computing devices that may be arranged, for example, in one or more server banks or computer banks or other arrangements. Such computing devices may be located in a single installation or may be distributed among many different geographical locations. For example, the computing system **103** may include a plurality of computing devices that together may comprise a hosted computing resource, a grid computing resource and/or any other distributed computing arrangement. In some cases, the computing system **103** may correspond to an elastic computing resource where the allotted capacity of processing, network, storage, or other computing-related resources may vary over time. The computing system **103** may implement one or more virtual machines that use the resources of the computing system **103**.

The computing system **103** includes a database **106**. The database **106** may represent one or more databases **106**. The database stores data such as, for example, an aggregated datalog **109**, tile data **112**, stoppage data **113**, candidate geofences **115**, and geofences **118**. The data stored in the database may embodied as a file or as intermediate, temporary data that is stored by a program providing complicated computations. The computing system **103** executes software programs such as, for example, a tracking application **121**, a geofencing application **124**, and a dashboard **127**. The

programs executed by the computing system **103** and the data stored therein is described in further detail below.

The computing network is designed to track a plurality of vehicles **130**. Each vehicle is equipped with a gateway **133**. A gateway **133** refers to a device installed in the vehicle to collect vehicle data. A gateway **133** may be embodied as, for example, an electronic logging device, a telemetry device, or any other electronic system that obtains vehicle data and transmits it a network **136**. A vehicle gateway **133** includes a processor, a memory system, a vehicle interface, and a communication module. The gateway sends messages **139** periodically over the network **136**. The network **136** may be, for example, the Internet, intranets, extranets, wide area networks (WANs), local area networks (LANs), wired networks, wireless networks, cellular networks, or other suitable networks, etc., or any combination of two or more such networks.

Also connected to the network **136** is a client device **142**. A client device **142** allows a user to interact with the components of the computing system **103** over a network **136**. A client device **142** may be, for example, a cell phone, laptop, personal computer, mobile device, or any other computing device used by a user. The client device **142** may include an application such as a web browser or mobile application that communicates with the computing system **103** to access, manipulate, edit, or otherwise process data transmitted over the network **136**.

Next, a general description of the operation of the various components of the computing system **103** is provided. Vehicles **130** are deployed in the field and may drive over a geographic area. Such vehicles **130** may be managed by one or more users who serve as a fleet manager. A gateway **133** is installed in each vehicle to track, monitor, and report vehicle activity. The gateway **133** interfaces with the vehicle to obtain the vehicle's speed, fuel level, diagnostics, vehicle system status, and other parameters associated with the vehicle. The gateway includes a location tracking module such as, for example, a Global Navigation Satellite System (GNSS) module to obtain geographic coordinates of the vehicle. The gateway **133** periodically transmits messages **139** over the network **136**. A message **139** may be referred to as a breadcrumb, packet, report, or status update. The message **139** may include the vehicle's speed and location. The message **139** may further include any vehicle reporting which encompasses various metrics and parameters associated with the vehicle that are obtained by the gateway **133**. Messages **139** may be transmitted periodically such as, for example, once every 30 seconds. In this respect, a message **139** is a sample of the vehicle's status. Receiving several messages **139** from a vehicle allows a vehicle to be tracked in real time.

A tracking application **121** executes in the computing system **103** for receiving and processing messages **139**. The tracking application **121** performs various operations such as, for example, establishing a tracking session for each gateway **133**, decoding and processing messages **139**, and storing messages in a database **106**. According to various embodiments, the vehicle tracking application **121** aggregates received messages **139** into an aggregated datalog **109**. In this embodiment, the tracking application **121** identifies field values in each message **139** and populates a database table which forms an aggregated datalog **109**. Each fleet of vehicles may have an aggregated datalog **109** that encompasses a comprehensive set of tracking data associated with each vehicle in the fleet. Moreover, a particular user account may organize its vehicles into multiple fleets.

A geofencing application **124** accesses the aggregated datalog **109** and processes it to generate one or more geofences **118** that may be recommended to a user. The geofencing application **124** derives stoppage data from the aggregated datalog **109** to identify instances where vehicles of a given fleet have stopped driving. Based on the stoppage data **113**, the geofencing application **124** identifies one or more candidate geofences by identifying clusters of vehicle stoppages. This process coarsely identifies candidate geofences **115** before generating a more specific geofence **118**. The use of candidate geofences as part of a coarse filtering analysis reduces processing constraints.

For a given candidate geofence **115**, the geofencing application **124** accesses the aggregated datalog **109** to identify additional vehicle stoppages within, near, or around the candidate geofence **118**. These additional vehicle stoppages may be determined using a different set of thresholds. Additional vehicle stoppages are binned into geospatial tiles using tile data **112**. Tile data **112** represents a collection of geospatial tile having a geographical boundary. Tile data **112** is used to map a geographic location to a corresponding tile. A tile may be a square, rectangle, triangle, pentagon, hexagon, or other polygon that is tessellated over a geographic area. Each tile has a boundary that is characterized by a geographic coordinate system. Thus, a single geographic coordinate corresponds with a tile by falling within the boundary of the tile. The tile data **112** provides tile maps for different tile sizes. Assuming hexagonal tiles are used, a tile size of 1.5 kilometers defines a first tile system with equal sized tiles having a diameter of 1.5 kilometers that are tessellated over a geographic space. If smaller tiles are preferred, using a 0.1 kilometer tile size leads to a second tile system with 0.1 kilometer tiles that are tessellated over the geographic space. This, of course, would lead to more tiles when compared to a tile system using larger tiles.

Locations of vehicle stoppages may be binned into corresponding tiles. A contiguous cluster of tiles with a high bin count yields a geofence **118** that is specific and tailored to actual data obtained from automatically tracking vehicles.

Users who manage a fleet of vehicles **130** may interface with the fleet tracking services of the computing system **103** by way of a dashboard **127**. A user uses a client device **142** to communicate with the computing system **103** over the network **136**. Using an application (e.g., web browser) or a dedicated application, the user has access to a dashboard **127**. The dashboard **127** provides a user with an overview of tracking data obtained from tracking a fleet of vehicles **130**. In addition, the dashboard **127** presents the geofence **118** to the user as a recommended geofence that the user may adopt as part of tracking a fleet.

FIG. 2A is a drawing illustrating an example of an aggregated datalog **109**, stored, processed, and accessed in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure. The aggregated datalog **109** includes data collected from a plurality of gateways **133** (FIG. 1) associated with corresponding vehicles **130** (FIG. 1). Each column represents data from a different gateway **133**. Each item for a given column has a corresponding timestamp. The aggregated datalog **109** may include data collected from the gateways **133** asynchronously such that the data from each message corresponds to a timestamp. The gateways **133** reporting the data in the aggregated datalog **109** may represent one or more fleets for a given user account. The example of FIG. 2A shows four samples worth of data. Messages transmitted from a given gateway **133** at a given time may include, for example,

location data and speed data. Location data may be formatted as geographic coordinates.

Gateway **001** in FIG. 2A represents a vehicle having a speed greater than or equal to 15 miles per hour over four samples. For these four samples, the speed may be considered large enough to infer that the vehicle associated with Gateway **001** has not stopped. Gateway **002** in FIG. 2A represents a vehicle having a speed that reduces to zero over a period of four samples such that it is in the process of stopping. Gateway **003** in FIG. 2A represents a vehicle having a speed of zero that begins to increase by the fourth sample. This represents a vehicle that is moving after it has stopped.

FIG. 2B is a drawing illustrating an example of stoppage data **113**, stored, processed, and accessed in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure.

Stoppage data **113** is calculated from the aggregated datalog **109**. According to various embodiments, the stoppage data **113** is determined for a subset of vehicles that contribute to the aggregated datalog **109**. In this respect, because the aggregated datalog **109** may continuously grow as additional messages **139** are received, the aggregated datalog **109** can be extremely large in size. Therefore, when determining a candidate geofence **115** (discussed in further detail below), embodiments of the present disclosure are directed to considering a subset of the aggregated datalog **109** when deriving stoppage data **113**. For example, the subset may be determined by identifying the vehicles that make up the largest fleet among several fleets belonging to a user account. Thus, the stoppage data **113** may reflect the stoppages of vehicles associated with a particular fleet but not all the fleets represented in the aggregated datalog **109**.

Various threshold configurations may be applied to generate the stoppage data **113** by analyzing the aggregated datalog **109**. The stoppage data **109** itemizes a plurality of vehicle stoppages and includes a location and a duration associated with each vehicle stoppage. To derive the vehicle stoppages, a geofencing application **124** (FIG. 1) may analyze the aggregated datalog **109** to identify instances where a vehicle gateway **133** has reported that a vehicle has no speed (e.g., a speed of zero or near zero to account for tolerance) for at least a predetermined period of time or a predetermined number of samples. For example, a vehicle stoppage may be defined as a vehicle having a speed of less than 0.25 miles per hour for at least 10 consecutive samples. This may account for signal noise when reading a vehicle's speed. In the example where each sample is taken once per minute, this translates to a vehicle that has not substantially moved for at least a 10-minute period. Upon identifying this instance in the aggregated datalog **109**, the geofencing application **124** updates the stoppage data **113** to record this vehicle stoppage along with a corresponding location and duration.

FIG. 2B shows six vehicle stoppages derived from the aggregate datalog **109**. Some of these vehicle stoppages show vehicles that have stopped nearby one another while others may be spread across a greater geographical area.

FIG. 3 is a drawing illustrating an example of operations performed by a geofencing application **124** that executes in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure. FIG. 3 shows a geofencing application **124** that identifies candidate geofences **115**, such as a first candidate geofence **115a** and a second candidate geofence **115b**. FIG. 3 also shows a tile system having several large tiles **304**. The geofencing application **124** uses a tile system with relatively large tile sizes

to provide a coarse estimate of where a candidate geofence **115** should be. The tile sizes may each have a large tile size such as, for example, a 150-meter diameter. FIG. 3 also shows several vehicle stoppages **307** plotted on a map.

The geofencing application **124** associates each vehicle stoppage **307** to a corresponding large tile **304**. Here, the geofencing application **124** uses the tile data **112** (FIG. 1) to determine which location of a given vehicle stoppage **307** is allocated to which large tile **304**. Upon completion, the geofencing application **124** identifies those large tiles **304** having a bin count that exceeds a threshold amount. The bin count refers to the number of vehicle stoppages located within a given tile. FIG. 3 shows in bold, two large tiles **304** having a number of vehicle stoppages exceeding a threshold of ten stoppages. Large tiles **304** that do not have a threshold number of vehicle stoppages are removed from consideration. The geofencing application **124** forms a candidate geofence **115a**, **115b** around each of the tiles that have a sufficiently large number of vehicle stoppages. As shown in FIG. 3, the diameter of the candidate geofence exceeds the tile size. According to various embodiments, the diameter of the candidate geofence is 450 meters while the large tile size is 150 meters.

To summarize FIG. 3, the geofencing application **124** identifies one or more coarsely defined geofences based on deriving vehicle stoppages from an aggregated datalog **109** or a subset of vehicle stoppages from the aggregated datalog **109**. FIG. 3 uses a first tile system having large tiles **304**.

FIGS. 4A and 4B are drawings illustrating an example of operations performed by a geofencing application that executes in a computing environment **100** of FIG. 1 according to various embodiments of the present disclosure. FIGS. 4A and 4B specifically show how the geofencing application **124** fine-tunes the geofencing calculations by starting with the coarsely defined candidate geofence **115**. FIGS. 4A and 4B build on the example of FIG. 3 by selecting one of the candidate geofences **115** and applying further processing to define a more specific boundary. In this respect, by determining a candidate geofence **115**, the geofencing application **124** limits the amount of data under consideration to make processing more manageable when generating a geofence **118**.

In FIG. 4A, the geofencing application **124** uses a second tile system based on a small tiles **407** that are smaller compared to the large tiles **304** of FIG. 3. The small tiles **407** of FIG. 4A may have, for example, a diameter of 10 meters. According to various embodiments, the geofencing application **124** accesses the entirety of the aggregated datalog **109** to identify all the vehicle stoppages within the candidate geofence **115**. For example, while the candidate geofence **115** is determined using one fleet, the geofence **118** is determined using multiple fleets or potentially all fleets that contribute to the aggregated datalog **109**.

The candidate geofence **115**, as shown in FIG. 4A is made up of a plurality of small tiles **407** that, together, roughly form a circular shape (e.g., all small tiles **407** are within or touching the boundary of the candidate geofence **115**).

In FIG. 4A, the geofencing application **124** bins each vehicle stoppage into a corresponding small tile **407** to determine a bin count for each tile. As shown, the number in each tile represents the number of vehicle stoppages associated within each small tile **407**. Some small tiles **407** have no vehicle stoppages, some have one, and some have more than 10. Small tiles having a bin count that exceeds a threshold (e.g., 10 vehicle stoppages) are shown in bold.

FIG. 4B shows small tiles **407** having a bin count that exceeds a threshold number of vehicle stoppages in black

and small tiles **407** having a bin count that falls below the threshold in white. Applying a threshold bin count yields a plurality of separate contiguous cluster of tiles including a first contiguous cluster of tiles **413**, a second contiguous cluster of tiles **416**, a third contiguous cluster of tiles **419**, and a fourth contiguous cluster of tiles **422**. The geofencing application **124** selects the largest contiguous cluster of tiles among the plurality, which is, in this case, the fourth contiguous cluster of tiles **422**. The boundary of the largest contiguous cluster of tiles **422** forms the geofence **118** calculated from the vehicle stoppage data **113**.

FIG. **5** is a flowchart illustrating an example of the functionality of the geofencing executed in a computing environment **100** of FIG. **1**. It is understood that the flowchart of FIG. **5** provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the portion of the geofencing application **124** as described herein. As an alternative, the flowchart of FIG. **3** may be viewed as depicting an example of elements of a method implemented in the computing system **103** (FIG. **1**) according to one or more embodiments.

At **505**, the geofencing application **124** accesses an aggregated datalog **109** (FIG. **1**). The computing system **103** (FIG. **1**) that executes the geofencing application **124** periodically receives messages **139** (FIG. **1**) from each of the plurality of vehicles **130** (FIG. **1**). Each message **139** may include, for example, a location sample and speed sample for a corresponding vehicle **130**. The computing system may aggregate the messages received from each of the plurality of vehicles to generate the aggregated datalog **109**. For example, the computing system may identify specific values (e.g., a speed, a location, etc.) in each message **139** and populate a database field that makes up the aggregated datalog **109**.

At **508**, the geofencing application **124** identifies vehicle stoppages. The stoppages identified may correspond to a subset of vehicles for a particular user account. A vehicle stoppage is an event where a vehicle is at rest or nearly at rest within a small vicinity for a particular period of time (e.g., 20 minutes, 10 hours). The geofencing application **124** derives the vehicle stoppages by analyzing the speed and location data for each vehicle **130** over a period of several samples. For example, the geofencing application determines whether the number of consecutive speed samples that indicate no speed for a vehicle **130** exceeds a threshold stoppage time. If a gateway **133** (FIG. **1**) reports no speed (e.g., a velocity that is zero or within a small range of zero to account for tolerance), the geofencing application **124** will determine the duration of time where there is no speed by counting the number of samples and accounting for the sample rate. Thus, if a vehicle **130** shows no speed for 20 samples with a sample rate of one sample per minute, then the geofencing application **124** infers that the vehicle **130** has stopped for 20 minutes. This information is recorded as a vehicle stoppage as part of the stoppage data **113**. The stoppage data **113** may include all the vehicle stoppages over a period of time based on threshold configurations of stoppage duration and speed tolerance. A stoppage may also be defined if the location data reported by a vehicle does not substantially change for a particular length in time (e.g., a change in location being less than 10 meters over a period of 5 minutes). Thus, the determination of a stoppage may be based on a little to no movement and/or little to no speed for a particular duration of time. According to an embodiment, there are three configurable parameters that define a vehicle stoppage: 1) the duration (e.g. 20 min to 10 hours); 2) the area or vicinity of movement (e.g. within a 30 meter

diameter) and 3) the maximum speed tolerated (e.g., less than 15 kilometers per hour). If all three parameters are met, the geofencing application **124** identifies this to be a stoppage.

At **512**, the geofencing application **124** bins the vehicle stoppages **307** into large tiles **304** (FIG. **3**). The geofencing application uses the tile data **112** to employ a first tile system using relatively large tiles **304** tessellated over a geographic region. Then, the geofencing application **124** counts how many vehicle stoppages **307** fall within each of the various large tiles **304**. The geofencing application **124** converts the location of each vehicle stoppage **307** to a corresponding large tile **304**.

At **515**, the geofencing application **124** determines a candidate geofence **115** (FIG. **1**). Here, the geofencing application applies a threshold number of vehicle stoppages to select the large tiles **304** that are associated with a sufficiently high bin count. According to various embodiments, the geofencing application **124** draws a boundary around each of these large tiles **304** to determine the candidate geofence **115**. The boundary may be a circle or other shape having a diameter that exceeds the diameter of the large tile **304**. Thus, the candidate geofence **115** may encompass a large tile **304** having a number of vehicle stoppages that exceeds a threshold as well as neighboring large tiles **304**.

At **518**, the geofencing application **124** identifies vehicle stoppages within the candidate geofence **115**. The geofencing application **124** may access the aggregated datalog **109** to identify all vehicle stoppages within a particular candidate geofence. For example, unlike at **508**, the geofencing application **124** considers a larger data set when determining vehicle stoppages.

At **521**, the geofencing application **124** bins the vehicle stoppages into small tiles **407** (FIG. **4A**). The geofencing application uses the tile data **112** to employ a second tile system using relatively small tiles **407** tessellated over a geographic region. Then, the geofencing application **124** counts how many vehicle stoppages **307** fall within each of the various small tiles **407**. The geofencing application **124** converts the location of each vehicle stoppage to a corresponding small tile **407**. The use of smaller tiles provides a more granular level of geofence definition based on first identifying a coarser candidate geofence **115**.

At **524**, the geofencing application **124** identifies small tiles having a bin count that exceeds a threshold. This operation identifies the small tiles **407** having the most frequent vehicle stoppages. At **527**, the geofencing application **124** clusters the small tiles. For example, the geofencing application **124** identifies clusters of contiguous tiles, where each tile in the cluster has a bin count that exceeds the threshold. A tile that shares any boundary with any adjacent tiles are considered to form contiguous tiles.

At **530**, the geofencing application **124** selects a cluster as the geofence **118**. For example, the geofencing application **124** may select the largest cluster as the geofence **118**, where the largest cluster is defined as the cluster having the most number of tiles. The boundary formed by the selected cluster is the boundary of the generated geofence **118**. The geofencing application **124** may convert the boundary of the cluster of tiles into geographic coordinates and store those coordinates in the database **106** as the geofence **118**. In addition, the geofence **118** may be processed to smoothen out the edges of the geofence **118**. This may involve, for example, applying a minimum convex hull around the geofence **118** to reduce the number of sides of the geofence **118**.

At **553**, the geofence application transmits the geofence **118** to the user. The geofencing application **124** works in conjunction with a dashboard **127** (FIG. **1**) to make the geofence available to the user. According to various embodiments, the geofence **118** is recommended to the user to be applied as part of a fleet tracking service. In addition, the user may label or edit a geofence **118** once it has been recommended by the dashboard **127**. For example, the user may stretch or shrink a rendering of the geofence as it is overlaid on a map. Edits to the geofence are stored in the database **106**.

FIG. **6** is a schematic block diagram that provides one example illustration of a computing system **103** of FIG. **1** according to various embodiments of the present disclosure. The computing system **103** includes one or more computing devices **600**. Each computing device **600** includes at least one processor circuit, for example, having a processor **603** and memory **606**, both of which are coupled to a local interface **609** or bus. To this end, each computing device **600** may comprise, for example, at least one server computer or similar device. The local interface **609** may comprise, for example, a data bus with an accompanying address/control bus or other bus structure as can be appreciated.

Stored in the memory **606** are both data and several components that are executable by the processor **603**. In particular, stored in the memory **606** and executable by the processor **603** is the tracking application **121**, geofencing application **124**, dashboard **127**, and other applications providing location tracking services. Also stored in the memory **606** may be a database **106** and other data such as, for example, user count data or data that organizes vehicles into fleets. In addition, an operating system may be stored in the memory **606** and executable by the processor **603**.

It is understood that there may be other applications that are stored in the memory **606** and are executable by the processor **603** as can be appreciated. Where any component discussed herein is implemented in the form of software, any one of a number of programming languages may be employed, such as, for example, C, C++, C#, Objective C, Java®, Swift, JavaScript®, Perl, PHP, Visual Basic®, Python®, Ruby, Go, or other programming languages.

Several software components are stored in the memory **606** and are executable by the processor **603**. In this respect, the term “executable” means a program file that is in a form that can ultimately be run by the processor **603**. Examples of executable programs may be, for example, a compiled program that can be translated into machine code in a format that can be loaded into a random access portion of the memory **606** and run by the processor **603**, source code that may be expressed in proper format such as object code that is capable of being loaded into a random access portion of the memory **606** and executed by the processor **603**, or source code that may be interpreted by another executable program to generate instructions in a random access portion of the memory **606** to be executed by the processor **603**, etc. An executable program may be stored in any portion or component of the memory **606** including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, USB flash drive, memory card, optical disc such as compact disc (CD) or digital versatile disc (DVD), floppy disk, magnetic tape, or other memory components.

The memory **606** is defined herein as including both volatile and nonvolatile memory and data storage components. Volatile components are those that do not retain data values upon loss of power. Nonvolatile components are those that retain data upon a loss of power. Thus, the

memory **606** may comprise, for example, random access memory (RAM), read-only memory (ROM), hard disk drives, solid-state drives, USB flash drives, memory cards accessed via a memory card reader, floppy disks accessed via an associated floppy disk drive, optical discs accessed via an optical disc drive, magnetic tapes accessed via an appropriate tape drive, and/or other memory components, or a combination of any two or more of these memory components. In addition, the RAM may comprise, for example, static random access memory (SRAM), dynamic random access memory (DRAM), or magnetic random access memory (MRAM) and other such devices. The ROM may comprise, for example, a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other like memory device.

Also, the processor **603** may represent multiple processors **603** and/or multiple processor cores and the memory **606** may represent multiple memories **606** that operate in parallel processing circuits, respectively. In such a case, the local interface **609** may be an appropriate network that facilitates communication between any two of the multiple processors **603**, between any processor **603** and any of the memories **606**, or between any two of the memories **606**, etc. The local interface **609** may comprise additional systems designed to coordinate this communication, including, for example, performing load balancing. The processor **603** may be of electrical or of some other available construction.

Although the software applications described herein may be embodied in software or code executed by general purpose hardware as discussed above, as an alternative the same may also be embodied in dedicated hardware or a combination of software/general purpose hardware and dedicated hardware. If embodied in dedicated hardware, each can be implemented as a circuit or state machine that employs any one of or a combination of a number of technologies. These technologies may include, but are not limited to, discrete logic circuits having logic gates for implementing various logic functions upon an application of one or more data signals, application specific integrated circuits (ASICs) having appropriate logic gates, field-programmable gate arrays (FPGAs), or other components, etc. Such technologies are generally well known by those skilled in the art and, consequently, are not described in detail herein.

The flowcharts discussed above show the functionality and operation of an implementation of the software applications. If embodied in software, each box may represent a module, segment, or portion of code that comprises program instructions to implement the specified logical function(s). The program instructions may be embodied in the form of source code that comprises human-readable statements written in a programming language or machine code that comprises numerical instructions recognizable by a suitable execution system, such as a processor **603** in a computer system or other system. The machine code may be converted from the source code, etc. If embodied in hardware, each block may represent a circuit or a number of interconnected circuits to implement the specified logical function(s).

Although the flowcharts show a specific order of execution, it is understood that the order of execution may differ from that which is depicted. For example, the order of execution of two or more boxes may be scrambled relative to the order shown. Also, two or more boxes shown in succession may be executed concurrently or with partial concurrence. Further, in some embodiments, one or more of the boxes may be skipped or omitted. In addition, any

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number of counters, state variables, warning semaphores, or messages might be added to the logical flow described herein, for purposes of enhanced utility, accounting, performance measurement, or providing troubleshooting aids, etc. It is understood that all such variations are within the scope of the present disclosure.

The software applications described above may also comprise software or code that can be embodied in any non-transitory computer-readable medium for use by or in connection with an instruction execution system such as, for example, a processor **603** in a computer system or other system. In this sense, the logic may comprise, for example, statements including instructions and declarations that can be fetched from the computer-readable medium and executed by the instruction execution system. In the context of the present disclosure, a “computer-readable medium” can be any medium that can contain, store, or maintain the logic or application described herein for use by or in connection with the instruction execution system.

The computer-readable medium can comprise any one of many physical media such as, for example, magnetic, optical, or semiconductor media. More specific examples of a suitable computer-readable medium would include, but are not limited to, magnetic tapes, magnetic floppy diskettes, magnetic hard drives, memory cards, solid-state drives, USB flash drives, or optical discs. Also, the computer-readable medium may be a random access memory (RAM) including, for example, static random access memory (SRAM) and dynamic random access memory (DRAM), or magnetic random access memory (MRAM). In addition, the computer-readable medium may be a read-only memory (ROM), a programmable read-only memory (PROM), an erasable programmable read-only memory (EPROM), an electrically erasable programmable read-only memory (EEPROM), or other type of memory device.

Further, any logic or application described herein, including software applications such as the tracking application **121**, geofencing application **124**, and the dashboard **127**, may be implemented and structured in a variety of ways. For example, one or more applications described may be implemented as modules or components of a single application. Further, one or more applications described herein may be executed in shared or separate computing devices or a combination thereof. For example, the software application described herein may execute in the same computing device **600**, or in multiple computing devices in the same computing system **103**. Additionally, it is understood that terms such as “application,” “service,” “system,” “engine,” “module,” and so on may be interchangeable and are not intended to be limiting.

Disjunctive language such as the phrase “at least one of X, Y, or Z,” unless specifically stated otherwise, is otherwise understood with the context as used in general to present that an item, term, etc., may be either X, Y, or Z, or any combination thereof (e.g., X, Y, and/or Z). Thus, such disjunctive language is not generally intended to, and should not, imply that certain embodiments require at least one of X, at least one of Y, or at least one of Z to each be present.

It should be emphasized that the above-described embodiments of the present disclosure are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Many variations and modifications may be made to the above-described embodiment(s) without departing substantially from the spirit and principles of the disclosure. All such modifications

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and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.

Therefore, the following is claimed:

1. A system comprising:

a processor; and

a memory coupled to a processor, the memory comprising a plurality of instructions, when executed, cause the processor to:

access a datalog comprising location samples and speed samples for a plurality of vehicles;

identify vehicle stoppages derived from the datalog, each vehicle stoppage corresponding to a respective stoppage location;

determine a candidate geofence based on a cluster of vehicle stoppages being within a predefined diameter, and further based on the size of the cluster exceeding a predetermined threshold of stoppages; associate each vehicle stoppage within the candidate geofence to a corresponding tile;

for each tile, determine a respective number of vehicle stoppages;

identify a contiguous cluster of tiles, wherein each tile within the cluster has a respective number of vehicle stoppages that exceed a predetermined threshold count; and

generate a geofence based on the boundary of the contiguous cluster of tiles, wherein the processor is configured to generate the geofence by determining that the contiguous cluster of tiles is the largest among a plurality of contiguous clusters of tiles within the candidate geofence.

2. The system of claim **1**, wherein the memory comprising the plurality of instructions, when executed, cause the processor to:

receive messages periodically from each of the plurality of vehicles, each message comprising a location sample and speed sample for a corresponding vehicle; and

aggregate the messages received from each of the plurality of vehicles to generate the datalog.

3. The system of claim **1**, wherein the processor is configured to identify the set of vehicle stoppages by determining whether the number of consecutive speed samples that indicate no speed for a vehicle exceeds a threshold stoppage time.

4. The system of claim **1**, wherein the processor is configured to determine the candidate geofence by:

identifying a tile within a first tile system, according to the size of the cluster exceeding the predetermined threshold of stoppages; and

applying the predetermined diameter that surrounds the tile.

5. The system of claim **4**, wherein the processor is configured to associate each vehicle stoppage to the corresponding tile using a second tile system, the second tile system comprising tiles that are smaller than the tiles of the first tile system.

6. A computer implemented method comprising:

determining a candidate geofence based on a cluster of vehicle stoppages derived from a datalog, the datalog comprising location samples and speed samples for a plurality of vehicles, wherein determining a candidate geofence based on a cluster of vehicle stoppages derived from a datalog further comprises determining whether a threshold stoppage time is exceeded by the number of consecutive speed samples that indicate no speed for a vehicle;

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accessing the datalog to identify a set of vehicle stoppages within the candidate geofence;
 associating each vehicle stoppage in the set to a corresponding tile;
 determining a respective number of vehicle stoppages for each tile;
 identifying a contiguous cluster of tiles, wherein each tile within the cluster has a respective number of vehicle stoppages that exceed a predetermined threshold count, wherein identifying the contiguous cluster of tiles, comprises:
 identifying a plurality of contiguous cluster of tiles; and
 selecting the contiguous cluster of tiles as the largest among the plurality of contiguous cluster of tiles;
 and
 generating a geofence based on the boundary of the contiguous cluster of tiles.

7. The method of claim 6, further comprising:
 receiving messages periodically from each of the plurality of vehicles, each message comprising a location sample and speed sample for a corresponding vehicle; and
 aggregating the messages received from each of the plurality of vehicles to generate the datalog.

8. The method of claim 6, wherein
 determining the candidate geofence comprises:
 identifying a tile based on a size of the cluster exceeding a predetermined threshold of stoppages and
 applying a predetermined diameter that surrounds the tile to define the boundary of the candidate geofence.

9. The method of claim 6, wherein associating each vehicle stoppage in the set to the corresponding tile comprises determining which hexagonal tile defined in a tile map contains the location associated with the vehicle stoppage.

10. The method of claim 6, further comprising transmitting the geofence to a client device.

11. One or more non-transitory computer-readable, non-volatile storage memory comprising stored instructions that are executable and, responsive to execution by a computing device, the computing device performing operations comprising:
 storing a datalog comprising location samples and speed samples for a plurality of vehicles;
 identifying a tile of a first tile size that contains a threshold number of vehicle stoppages, the number of vehicle stoppages being derived from the datalog;
 identifying a set of vehicle stoppages within a candidate geofence defined around the tile;

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associating each vehicle stoppage in the set to a corresponding tile of a second tile size;
 determining a respective number of vehicle stoppages for each file of the second tile size;
 identifying a contiguous cluster of tiles of the second tile size, wherein each tile within the contiguous cluster has a respective number of vehicle stoppages that exceed a predetermined threshold count; and
 generating a geofence based on the boundary of the contiguous cluster of tiles.

12. The one or more non-transitory computer-readable, non-volatile storage memory of claim 11, wherein the second tile size is smaller than the first tile size and wherein the candidate geofence comprises a diameter greater than the first tile size.

13. The one or more non-transitory computer-readable, non-volatile storage memory of claim 11, wherein the computing device further performs operations comprising:
 receiving messages periodically from each of the plurality of vehicles, each message comprising a location sample and speed sample for a corresponding vehicle; and
 aggregating the messages received from each of the plurality of vehicles to generate the datalog.

14. The one or more non-transitory computer-readable, non-volatile storage memory of claim 11, the number of vehicle stoppages is derived from the datalog by determining whether the number of consecutive speed samples that indicate no speed exceeds a threshold stoppage time.

15. The one or more non-transitory computer-readable, non-volatile storage memory of claim 11, wherein identifying the contiguous cluster of tiles of the second tile size comprises:
 identifying a plurality of separate contiguous clusters of tiles; and
 selecting the contiguous cluster of tiles as the largest among the plurality of separate contiguous cluster of tiles.

16. The one or more non-transitory computer-readable, non-volatile storage memory of claim 11, wherein associating each vehicle stoppage in the set to the corresponding tile of the second tile size comprises determining which hexagonal tile defined in a tile map contains the location associated with the vehicle stoppage.

17. The one or more non-transitory compute readable, non-volatile storage memory of claim 11, wherein the computing device further performs operations comprising transmitting the geofence to a client device.

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